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Influence of Posture-Cuing Shirt on Tennis Serve Kinematics in Division III Tennis Players

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Comments

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Abstract (word count = 237)

Objective: Injuries to the shoulder complex are common in overhead athletes, often related to kinematics of the shoulder complex. This study evaluated the influence of a posture-cuing shirt on internal rotation velocity of the shoulder during a tennis swing and to determine this influence on shoulder external rotation position. **Methods:** Nine healthy competitive college tennis players from a Division III college participated in this study. High speed motion capture allowed for 3-D analysis of shoulder kinematics during a tennis serve. Two conditions were evaluated while the athletes performed a high velocity tennis serve: standard tennis shirt and a posture-cuing shirt. **Results:** Shoulder internal rotation velocity increased when wearing the PC shirt. Peak internal rotation velocity increased from 960.61 degrees/second $\pm$ 93.24 degrees/second to 1217.96 degrees/second $\pm$ 155.01 degrees/second ($t = -1.76$, $p = 0.058$). Internal rotation velocity at the time of impact increased from 765.18 degrees/second $\pm$ 95.48 degrees/second) to 900.54 degrees/second $\pm$ 105.33 degrees/second) ($t = -1.50$, $p = 0.086$). Shoulder maximum external rotation did not differ between the two conditions, at 172.00 degrees $\pm$ 2.92 degrees and 170.89 degrees $\pm$ 3.70 degrees ($t = 0.325$, $p = 0.754$). **Conclusions:** Wearing a posture-cuing shirt has the potential to alter shoulder kinematics during an overhead sport activity such as tennis. Internal rotation velocity improved while wearing this shirt, while shoulder external rotation position did not change. It is not known if these improvements can influence injury risk.

The anatomy of the shoulder joint presents unique problems for overhead athletes, such as tennis players, baseball pitchers and volleyball players. The effective and efficient function of the shoulder complex requires the coordinated movements of the scapula, clavicle, and glenohumeral joint.[1] Instability of the glenohumeral joint, altered kinematics of scapular motion, and muscle imbalances of the shoulder complex place overhead athletes at increased risk for shoulder injury.[2-5] These functions have been associated with injury risk and/or dysfunction specific to the glenohumeral joint, which is dependent on proper scapular motion during upper extremity activities.[5-7]

With tennis in particular, the tennis serve is considered the most important stroke in this sport and is also considered the most influential on injury occurrence to the shoulder in tennis players.[8,9] The tennis serve involves the coordinated effort of the lower extremities and trunk, and also the integrated motions of the scapula with the humerus.[9] Not surprisingly, shoulder internal and external rotation motions, which are dependent on scapular positioning, are associated with shoulder injury in athletes, including tennis players.[9,10] For instance GIRD (glenohumeral internal rotation deficit), which is defined as the imbalance of shoulder arc of rotation, creating excessive external rotation and a lack of internal rotation ROM, is associated with scapular dyskinesia and subsequent injury to the shoulder of overhead athletes[3,10-12] As noted in prior studies, shoulder internal rotation is directly associated with racquet speed and ball velocity after impact, and shoulder external rotation is associated with shoulder internal rotation function.[8-10] Hence, effective movement of the glenohumeral joint, during the tennis serve, is a critical element to the mechanics of the serve but also critical to minimizing the risk of injury to the shoulder.

A recent adjunct to shoulder prevention and rehabilitation programs is the addition of kinesiotape. Kinesiotaping has been shown to increase both muscle activation and ROM when used in conjunction with training programs.[13] It has also been shown to improve the resting position of the scapula.[14] Along with improving the starting position of the scapula, Shaheen et al[15](2013) found that taping increased ROM of scapular retraction, upward rotation, and posterior tilting in asymptomatic patients. Finally, taping has also been shown to increase serratus activation during entire range of scaption (shoulder abduction in the plane of the scapula), as well as facilitate the activation of the lower trapezius.[16] Since normal scapular positioning and ROM have been proven to be important in injury prevention, taping may be a great supplemental treatment for athletes. [13,14,17]

A unique garment recently introduced to the athletic community is a posture-cuing shirt that attempts to replicate the influence of kinesiotape on upper body posture, including scapular positioning. This shirt is designed to reproduce the kinesiotape influence of the shoulder girdle, particularly the scapula. The shirt is also compressive in nature which is linked to overall improved recovery.[18,19] Limited research exists as to the effectiveness of these posture-cuing shirts on shoulder function. Cole et al[20] found that these types of shirts with tension have improved the postural alignment of the shoulder, decreased forward shoulder posture, and increased activation of the lower trapezius during scaption and flexion in overhead athletes with forward-head, rounded-shoulder posture. Russell et al[21] (2013) also found that the posture-cuing shirt improved function for pitchers. These studies support the need for more research on such technology, specifically in populations prone to upper extremity injuries.

The purpose of this study was to determine any influence of a compressive posture-cuing shirt on the kinematics of the glenohumeral joint during a tennis serve. This preliminary study attempted to determine if a posture-cuing shirt has any impact on joint kinematics (i.e., joint positioning and joint motion) during an overhead tennis serve, given that prior research on kinesiotape and posture-cuing shirts demonstrated influence on scapular positioning. It was hypothesized that the posture-cuing shirt, reported to influence the scapula and upper torso, would provide a change in joint kinematics of the glenohumeral joint during an overhead tennis serve. We focused on internal rotation velocity, which is associated with ball velocity of a serve, and shoulder external rotation position, which is associated with GIRD and shoulder function.[10]

Methods

Subjects. Subjects were recruited from a Division III University Tennis program. Participants included 4 men (X_{age} = 19.5 $\pm$ 1.3 years; X_{ht} = 1.78m $\pm$ 0.05) and 5 women (X_{age} = 20.0 $\pm$ 0.71 years; X_{ht} = 1.66m $\pm$ 0.04), and all had a minimum of 3 years competitive tennis experience. Participants were healthy with no recent history of upper extremity injuries in the past 6 months. This study was granted exemption status by the University's Institutional Review Board.

Procedures. All subjects completed a standard warm-up as prescribed by the tennis program. The participants then completed two full serves, at game speed effort. One serve (control) was performed while wearing the standard athletic clothing for the participant. A second serve (PC shirt) was performed while wearing the posture-cuing shirt. Order of the conditions was not randomized; all participants performed the control condition first and the PC shirt condition second. Participants were not blinded to the two conditions.

Data were collected using a 3-D motion analysis system. This system included 2 high speed cameras at a rate of 240Hz (EXZR200 cameras, Casio Computers LTD), positioned at approximately orthogonal to the athlete, with 1 camera parallel to the serve line and the 2nd camera positioned at approximately 90 degrees, from an anterior view of the subject. Prior to collecting movement data, the capture field was calibrated using an 8-point DLT (direct linear transformation) object placed in the serve area. The optical data were then digitized using Motus software (Vicon Motus, version 10.0, Vicon, Englewood NY), identifying joint centers for the shoulder, elbow, wrist, hand, and torso, as well as identifying markers in the center of the tennis handgrip and the head of the racquet. The 2D data were first smoothed with FFT (fast fourier transformation) using a 28ms window. In addition, the elbow (6Hz) and wrist (14Hz) were filtered using a Butterworth low-pass filter. The filtered 2D data were then incorporated into a vector system to produce 3D coordinates, using a Butterworth filter at 13Hz. Anatomical references were then created using these 3D filtered coordinates to produce a linkage system to calculate the kinematic data. All kinematic data were calculated using the Zenolink software program (ZenoLink, Endicott NY). The variables of interest focused on joint angular positions and angular velocities of the glenohumeral joint. Specifically, peak internal rotation velocity, peak external rotation position, and internal rotation velocity at the time of impact with the tennis ball, were all estimated.

Data Analysis. Kinematic data of should positions (peak shoulder external rotation, peak internal rotation velocity, internal rotation velocity at impact) were averaged across the subjects. Paired t-tests were used to determine if differences existed between the control condition and the PC shirt condition. Because this was an exploratory study, a p-value of 0.10 was established a priori in order to identify potentially clinically relevant trends.

Results.

Shoulder internal rotation velocity increased when wearing the PC shirt. Peak internal rotation velocity increased from 960.61 degrees/second (se = 93.24) to 1217.96 degrees/second (se = 155.01), t = -1.76, p = 0.058). Internal rotation velocity at the time of impact increased from 765.18 degrees/second (se = 95.48) to 900.54 degrees/second (se = 105.33), t = -1.50, p = 0.086. Shoulder maximum external rotation did not differ between the two conditions, at 172.00 degrees (se = 2.92) and 170.89 degrees (se = 3.70), t = 0.325, p = 0.754.

Discussion.

The results showed there was a significant increase in both peak internal rotation velocity and internal rotation velocity at the time of impact while wearing the PC shirts. There were no significant changes in maximum shoulder external rotation. In terms of improved performance, we can only speculate that the improved shoulder internal rotation velocity might result in improved ball velocity after contact with the racquet; we did not measure ball velocity in this study. However prior research by Sprigings et al (1994) demonstrated that racquet-head speed was most dependent on shoulder internal rotation velocity.[10] Our results are fairly consistent with prior research in terms of peak internal rotation velocity, with values ranging from 620 degrees/second in trained tennis players to 1370 degrees/second in professional female tennis players.[22,23] However, the magnitude of external rotation position in our study exceeds that of other researchers (115 – 140 degrees).[22,24]

The changes in internal rotation speed may be attributed to changes in scapular positioning while wearing the PC shirts given the reported influence of a posture-cuing shirt on scapular and torso posture, as well as the influence of Kinesiotaping on scapular motion.[1,14,16,20] However, this is only conjecture as we did not study the scapular motion and base this assumption on prior research. Ujino et al. (2013) hypothesized that "KT (kinesiotape) may have placed the scapula more posterior which may increase activation of shoulder musculature."[14, 16] PC shirts were shown to provide similar influence, as noted by Cole et al (2014).[20] They observed that "Tension straps on postural cueing shirts decrease forward shoulder angle and alters some muscle activity" resulting in a decrease in upper trapezius and an increase in lower trapezius muscle activity during shoulder flexion while wearing a PC shirt. These improvements in scapular motion, either with KT or PC, are attributed to improved function of the glenohumeral joint during overhead motions.[14,16,20] We observed improved speed of the glenohumeral joint while the athletes wore the PC shirt, yet we did not observe any changes in glenohumeral external rotation. If the PC shirt did in fact influence scapular positioning, we suspect this would improve internal rotation speed, but we also would suspect a change in shoulder external rotation, which we did not observe. And, because we did not evaluate scapular position in our particular study, any explanation for the improvement in glenohumeral internal rotation speed is speculative.

The PC shirts may also increase the tactile input, influencing the time to activate the muscles of the scapula stabilizers to maintain a stable base for the humeral internal rotators to function. KT has been shown to "provide additional sensory feedback ... pressure and stretching effect of KT stimulates cutaneous mechanoreceptors which conveys information about joint position and movement therefore enhancing proprioception".[13] Cole et al. (2014) also hypothesized that PC shirts would have the same effect as KT, “slight EMG changes in both conditions (compression shirts with or without tension straps) might suggest an effect on joint alignment due to enhanced proprioception and proprioceptive feedback.”[20] We can only postulate that the posture-cuing shirt might have influenced muscle activation, which may have contributed to the changes in internal rotation velocity of the shoulder. However, just as with scapular positioning, we did not assess muscle activity in this current study and thus this relationship is speculative.

Some additional limitations to this study are the small number of subjects due to the specific inclusion criteria. Subjects only completed one serve in each condition leading to possible error; more trials would decrease the amount of error and increase the validity and reliability of the results. The motion capture system employed in this study has proven reliability in previous dynamic studies; however we did not directly measure the error in this study.[23] The subjects were also not randomized as to which condition they performed first; all subjects performed first with normal clothing then with the PC shirt. The lack of randomization could have led to an order effect or even a placebo effect due to the athletes’ expectations of the PC shirts. Also starting scapular position was not measured so the cause for the change in velocity can only be theorized. Future research should address long term effects of PC shirts. A longitudinal study should address strength, starting alignment, and ROM. Long term changes in any of these categories can give us a better insight into functional changes like velocity while wearing PC shirts. In addition, it will be important to study the influence of PC shirts on scapular kinematics, in order to better appreciate any possible relationship between glenohumeral motion and scapular motion, while wearing a PC shirt. Finally, given the demonstrated influences of KT on scapular and shoulder kinematics, a comparison study between PC and KT on overhead kinematic activities such as the tennis serve, are highly warranted.

Conclusion

This study provides preliminary findings that suggest a posture-cuing shirt might provide influence on glenohumeral joint motion during overhead activities such as a tennis serve. Specifically, a change in relative internal rotation velocity of the shoulder was observed when athletes wore a posture-cuing shirt. Whether this is a result of a change in glenohumeral joint positioning, scapular motion, or muscle activation is subject for future research.

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